RESPIRATION PHYSIOLOGY

INDEXING PROBLEMS

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Preliminary Note

In the pages which follow, terms appearing in capital letters are terms found as main headings in MEDICAL SUBJECT HEADINGS (MeSH), for example, SPIROMETRY; ACID-BASE EQUILIBRIUM; etc. Terms frequently encountered in the literature but for which no MeSH headings exist at this writing are typed in lower case and are underlined (oxygen dissociation curve; ventilation-perfusion ratio).

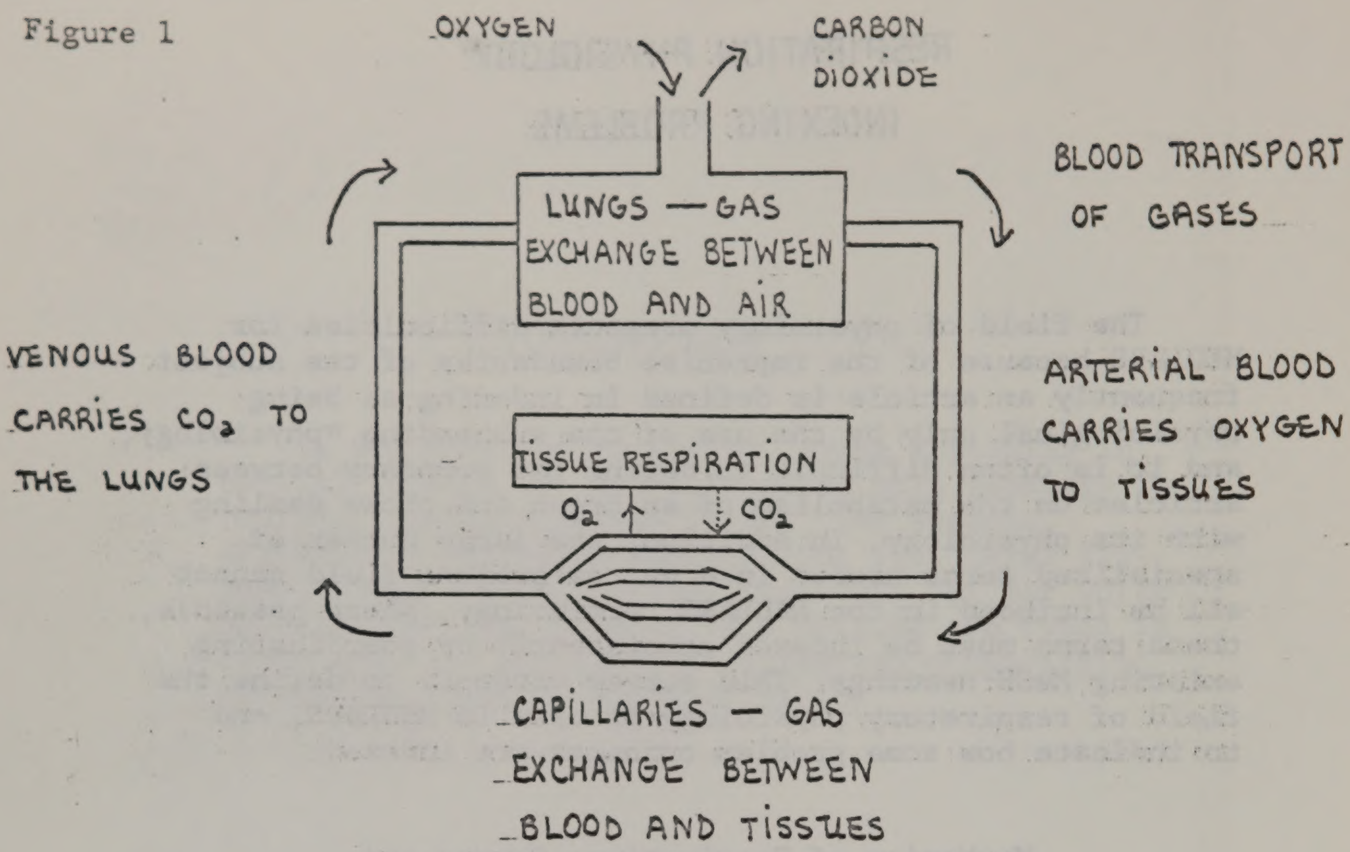
RESPIRATION PHYSIOLOGY
INDEXING PROBLEMS

The field of physiology presents difficulties for MEDLARS because of the imprecise boundaries of the subject -- frequently an article is defined in indexing as being physiological only by the use of the subheading *physiology, and it is often difficult to define the boundary between articles on the metabolism of an organ and those dealing with its physiology. In addition, the large number of specialized terms needed in a narrow subject field cannot all be included in the MEDLARS terminology. Where possible, these terms must be indexed consistently by coordinating existing MeSH headings. This survey attempts to define the field of respiratory physiology as used in MEDLARS, and to indicate how some problem concepts are indexed.

Mechanism of Respiration; Oxygen and Carbon Dioxide; Tissue Respiration

Respiration in its widest sense covers gas exchange between the organism and its environment, the transport of gases to and from the tissues, and the chemical reactions occurring in the cell -- using oxygen, producing carbon dioxide, and liberating energy used by the cell to maintain its life process. Figure 1 outlines the whole process. Gas exchange between the air and the blood occurs in the lungs. Oxygen passes into the blood from the air and carbon dioxide is removed from the blood Arterial blood carries oxygen from the lungs to the tissues. In the capillaries oxygen diffuses from the blood into the tissues and

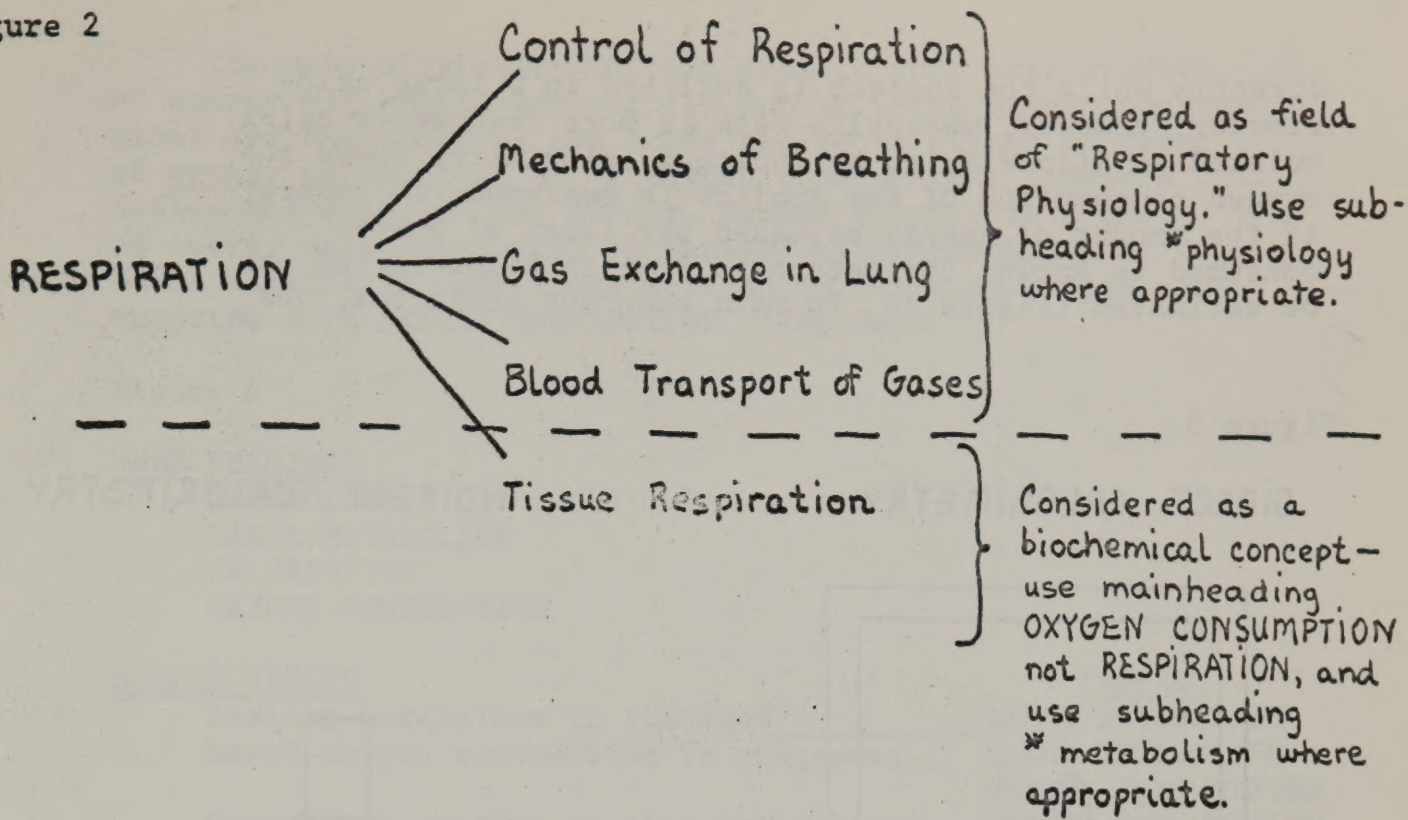
Figure 1



is used by the tissue cells in their metabolic process (tissue respiration). The carbon dioxide produced in tissue respiration passes into the capillaries and is carried by the venous blood back to the lungs where it passes into the expired air.

The main processes involved in respiration are listed in Figure 2: The control of respiration by the central nervous system, the mechanics of breathing, gas exchange in the lung, and blood transport of gases are all considered from the MEDLARS point of view to be included in the field of respiratory physiology. For these the main heading RESPIRATION is used and not RESPIRATORY SYSTEM *physiology. Tissue respiration, however, is considered to belong more to the field of biochemistry than to

Figure 2



physiology, and articles on it are indexed with the term OXYGEN CONSUMPTION rather than RESPIRATION, with the subheading *metabolism used where appropriate.

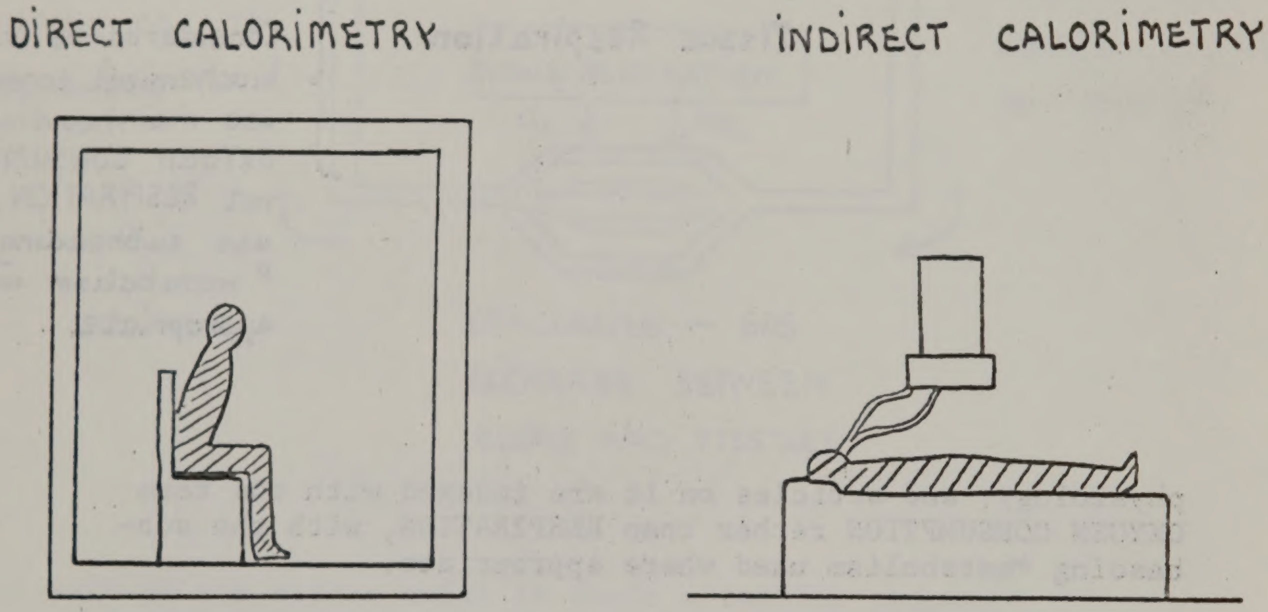
Metabolism, Basal Metabolism and Calorimetry

Gas exchange in the lungs and blood transport of oxygen and carbon dioxide are considered as physiological processes, and tissue respiration as metabolism, using metabolism in the sense of chemical changes occurring in the tissues. However, the term metabolism can also be used for the sum of chemical and energy transformations in the body as a whole: the metabolic rate is the rate of energy production of the whole body and is usually expressed in kilocalories per day; i.e., as heat energy.

The metabolic rate can be measured by direct calorimetry. The heat production of a human subject or animal is measured

directly while the subject is enclosed in a large calorimeter. However, metabolic rate is more frequently calculated in kilocalories by indirect calorimetry where the oxygen consumption of the subject is measured, and where, if the amount of energy released per liter of oxygen consumed is known, the metabolic rate in kilocalories can be estimated (Figure 3). To make accurate estimates, the

Figure 3



amount of carbon dioxide produced and the amount of nitrogen excreted need to be known so that the relative amounts of fat, protein and carbohydrates being oxidized in the body can be estimated.

The MeSH headings available in this subject area are METABOLISM, BASAL METABOLISM, CALORIMETRY and OXYGEN CONSUMPTION, and sample titles might be "Resting metabolism in the aged," "Basal oxygen consumption in pregnancy," "Oxygen consumption in sleeping Eskimos," "Maximal oxygen consumption in exercise," "Energy expenditure in adolescents," "Energy metabolism of the chimpanzee," amd "Energy cost of walking."

The main difficulty in this area is that most studies of energy metabolism are carried out by using oxygen consumption; and that authors can treat the topic either in terms of energy expenditure or of oxygen consumption. Indexers will follow the usage of the author. Papers written in terms of energy metabolism will be indexed with METABOLISM or BASAL METABOLISM, and those written in terms of oxygen consumption with OXYGEN CONSUMPTION. (Figure 4)

Figure 4

MeSH HEADINGS

- METABOLISM
- BASAL METABOLISM
- CALORIMETRY
- OXYGEN CONSUMPTION

SAMPLE TITLES	INDEXED
Resting metabolism in the aged	BASAL METABOLISM
Basal oxygen consumption in pregnancy	BASAL METABOLISM OXYGEN CONSUMPTION
Oxygen consumption in sleeping Eskimos	OXYGEN CONSUMPTION
Maximal oxygen consumption in exercise	OXYGEN CONSUMPTION
Energy expenditure of adolescents	METABOLISM
Energy metabolism of the chimpanzee	METABOLISM
Energy cost of walking	METABOLISM

TO SUMMARIZE

Index Energy Metabolism as METABOLISM or BASAL METABOLISM
Index Oxygen Consumption as OXYGEN CONSUMPTION

The MeSH heading BASAL METABOLISM should be used only for studies of the metabolism of subjects in the basal state, that is, in subjects who are awake but at rest and in a postabsorptive state (12 hours after eating and at a comfortable environmental temperature). The papers on "Resting metabolism in the aged" and "Basal oxygen consumption in pregnancy" fit this definition, and are indexed with BASAL METABOLISM. Since the second paper mentions oxygen consumption too, it is indexed with this term also.

The paper on "Oxygen consumption in sleeping Eskimos" is indexed with OXYGEN CONSUMPTION, but not with BASAL METABOLISM for the subjects were not in the basal state. "Maximal oxygen consumption in exercise" is indexed with OXYGEN CONSUMPTION.

The three papers in which the main theme is energy expenditure or energy metabolism are indexed with METABOLISM as a print heading. However, if in these papers the author states that the studies were made by measuring oxygen consumption, this term may also be used as a non-print heading.

CALORIMETRY is defined by MeSH as "measurement of the amount of heat absorbed or given out." It is used only for descriptions of the technic of calorimetry where the heat output is actually measured directly, and never for theoretical discussions of energy metabolism. Since indirect calorimetry involves measurement of oxygen consumption only, and not of actual heat production, the term CALORIMETRY cannot be used. Articles on indirect calorimetry are indexed with OXYGEN CONSUMPTION.

OXYGEN CONSUMPTION can be used either for oxygen consumption of the cell or of the whole organism.

An article on the effect of epinephrine on respiration in muscle tissue is indexed MUSCLES *metabolism, EPINEPHRINE *pharmacodynamics, OXYGEN CONSUMPTION *drug effects and MUSCLES *drug effects (Figure 5). The terms marked with an X are print terms, i.e., the citation will appear under these headings in INDEX MEDICUS.

Figure 5

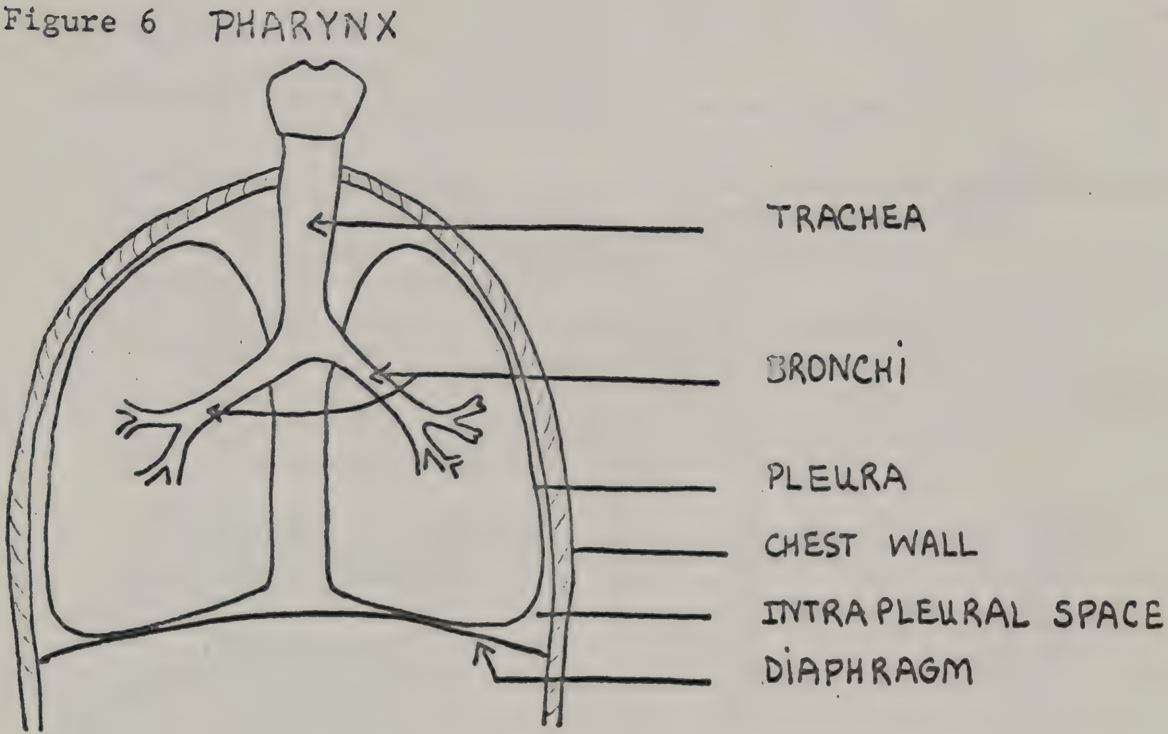
title:	The effect of epinephrine on respiration in muscle tissue
index:	X MUSCLES *metabolism X EPINEPHRINE *pharmacodynamics X OXYGEN CONSUMPTION *drug effects MUSCLES *drug effects

The combination MUSCLES *drug effects is indexed for computer storage for researchers interested in the effects of drugs on muscles, without reference specifically to respiration of muscle tissue.

Mechanics of Breathing: Respiratory Tract Anatomy

In order to describe the mechanics of breathing, it is first necessary to discuss the anatomy of the lungs and respiratory airways. Figure 6 shows this arrangement.

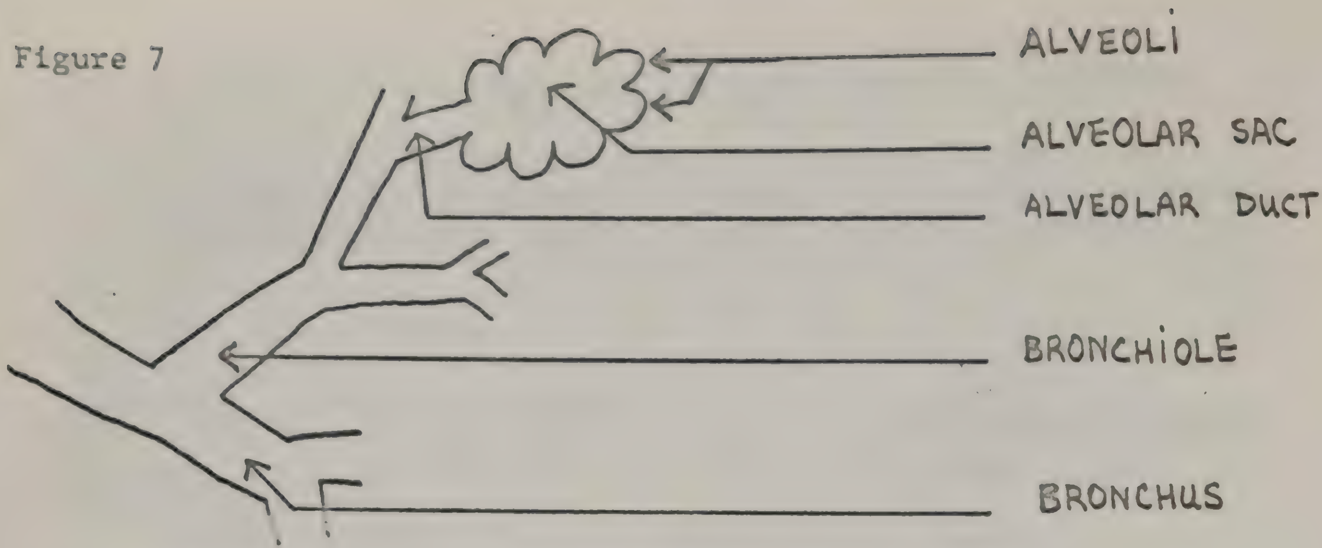
Figure 6



The pharynx acts as a passage for both food and air. During swallowing the opening from the larynx into the pharynx is closed by the epiglottis which acts like a valve to prevent food from entering the airways.

From the larynx, air passes down the trachea which forks to form the right and left primary bronchi supplying the right and left lungs. The primary bronchi subdivide into secondary and tertiary bronchi, and finally into

Figure 7



small tubes called bronchioles which finally communicate with alveolar sacs lined by minute pockets called alveoli (Figure 7). The walls of the alveoli are richly supplied with capillary blood vessels and it is here that the gas exchange between the air and the blood takes place.

The MeSH terms available for the anatomy of the respiratory system are found in Category A4 (Figure 8).

Figure 8

A4 RESPIRATORY SYSTEM
- NOSE *
- PARANASAL SINUSES *
- LARYNX *
- TRACHEA
- BRONCHI
- LUNG
  - PLEURA
  - PULMONARY ALVEOLI

Respiratory Airways
- airways resistance

- airways obstruction
  - RESPIRATORY TRACT DISEASES (IM)

Bronchoconstriction
- BRONCHI *physiology (IM)
- CONSTRICTION (NIM)

Bronchodilatation
- BRONCHI *physiology (IM)
- DILATATION (NIM)

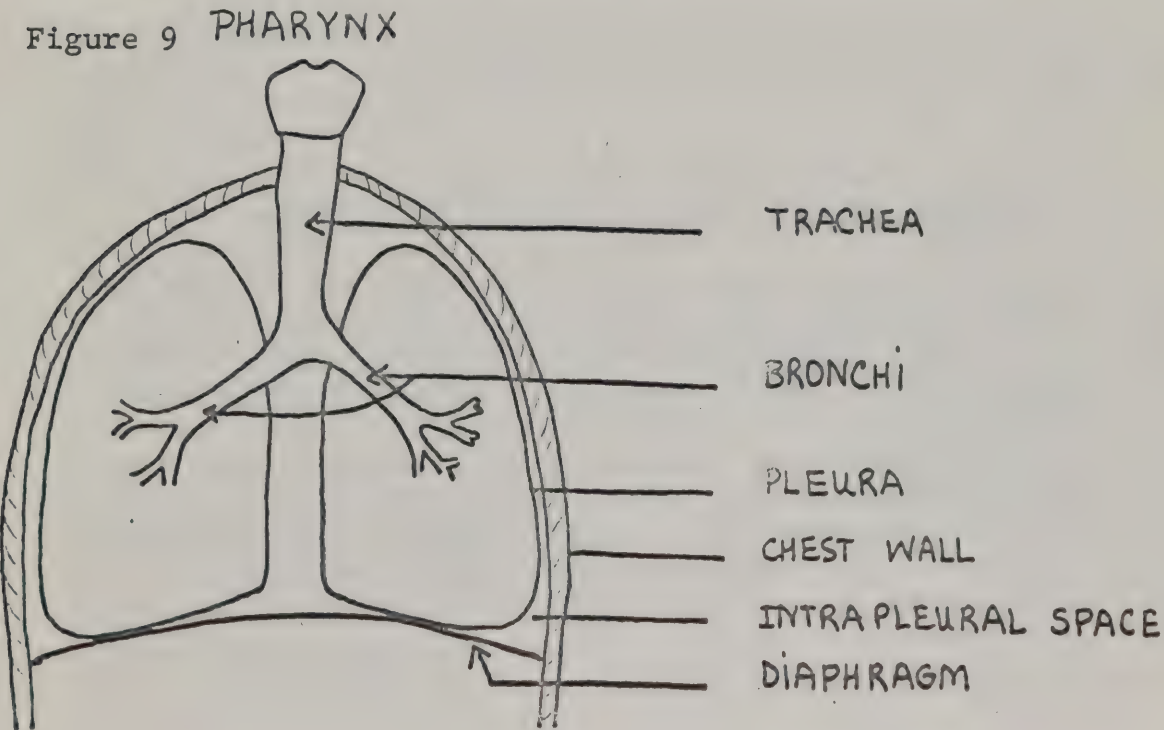
Isolated Trachea or Bronchi
- TRACHEA or BRONCHI
- MUSCLE, SMOOTH

The terms marked with an asterisk are expanded further; for example, the individual paranasal sinuses are named. The main problem here is that it is not possible to specify respiratory airways, a concept commonly used, for instance, in papers on airways resistance or airways obstruction. Papers on airways obstruction should be indexed under RESPIRATORY TRACT DISEASES.

The walls of the trachea, bronchi and bronchioles contain smooth muscle which can contract, narrowing the diameter of the airways. The terms bronchoconstriction and bronchodilatation are frequently seen in the literature. They are indexed as BRONCHI *physiology and the provisional heading CONSTRICTION, and BRONCHI *physiology and the provisional heading DILATATION, respectively. Note, however, that bronchial constriction at a clinical level is sometimes the disease term BRONCHOSPASM. The isolated trachea or bronchus is sometimes used as a test preparation for studying tracheal or bronchial smooth muscle. Papers on this topic should be indexed with TRACHEA or BRONCHI and MUSCLE, SMOOTH. The slant of the article will determine which is IM and which NIM.

The lungs are not connected with the chest wall. They lie in the pleural cavity. (Figure 9)

Figure 9



A serous membrane, the pleura, covers the surface of the lungs and lines the inside of the chest wall; the space it encloses is called the pleural cavity or intrapleural space. A sheet of muscle, the diaphragm, separates the thorax and abdomen, and forms the lower boundary of the pleural cavity.

The lungs under normal conditions practically fill the pleural cavity with only a thin layer of pleural fluid separating them from the chest wall. The lungs are elastic and exert an inward pull, so that there is a negative pressure in the pleural cavity. If the chest wall were perforated, the lung would collapse and the pleural cavity would fill with air, a condition called PNEUMOTHORAX. In normal conditions, however, air cannot enter the pleural space and the lungs follow the movements of the chest wall and diaphragm. Inspiration is brought about by the contraction of the inspiratory muscles (the diaphragm and external intercostal muscles). The diaphragm, which is normally concave, flattens, increasing the volume of the thoracic cavity, and the external intercostal muscles lift the rib cage, a movement which increases the volume of the chest. Normal quiet expiration is a passive process: the lung and chest wall are elastic structures and their recoil is sufficient to drive air out of the lungs. The expiratory muscles (the internal intercostals and the abdominal muscles) come into action during vigourous breathing and force air out of the lungs.

Mechanics of Breathing:
Lung Elasticity, Compliance and Resistance

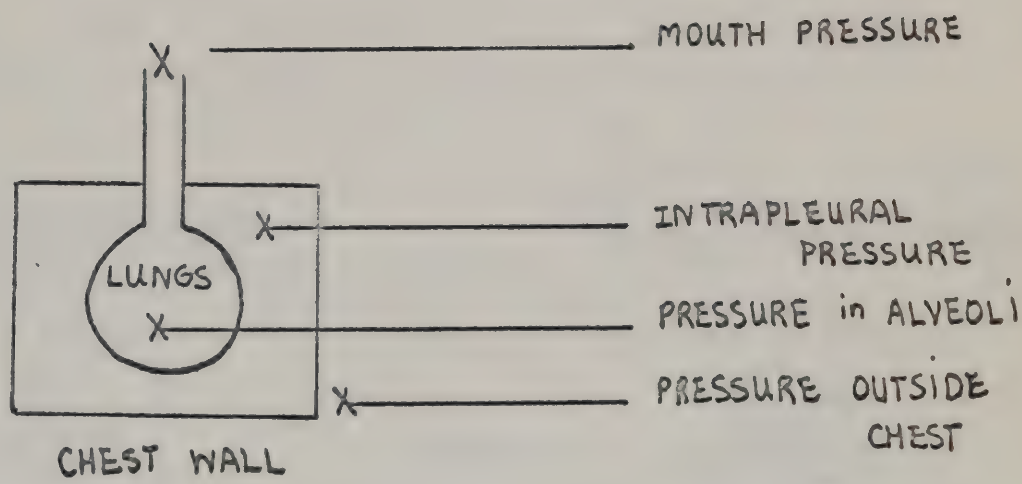
Studies of the mechanics of respiration can be divided into studies of the <u>static</u> properties of the respiratory system (i.e., the <u>elasticity</u> of the lungs and chest wall) and <u>dynamic</u> studies (i.e., <u>resistance</u> to air flow during respiration).

The measure of lung elasticity most commonly used is COMPLIANCE, defined as the volume change of the lung per unit change of pressure $\frac{\Delta V}{\Delta P}$. The greater the compliance, the greater the "give" of the lung when air is pumped into it. The lung can be considered an elastic balloon

inside an elastic container, the chest wall. To study compliance and resistance (Figure 10), volume changes and pressure changes are measured.

Figure 10

COMPLIANCE AND RESISTANCE

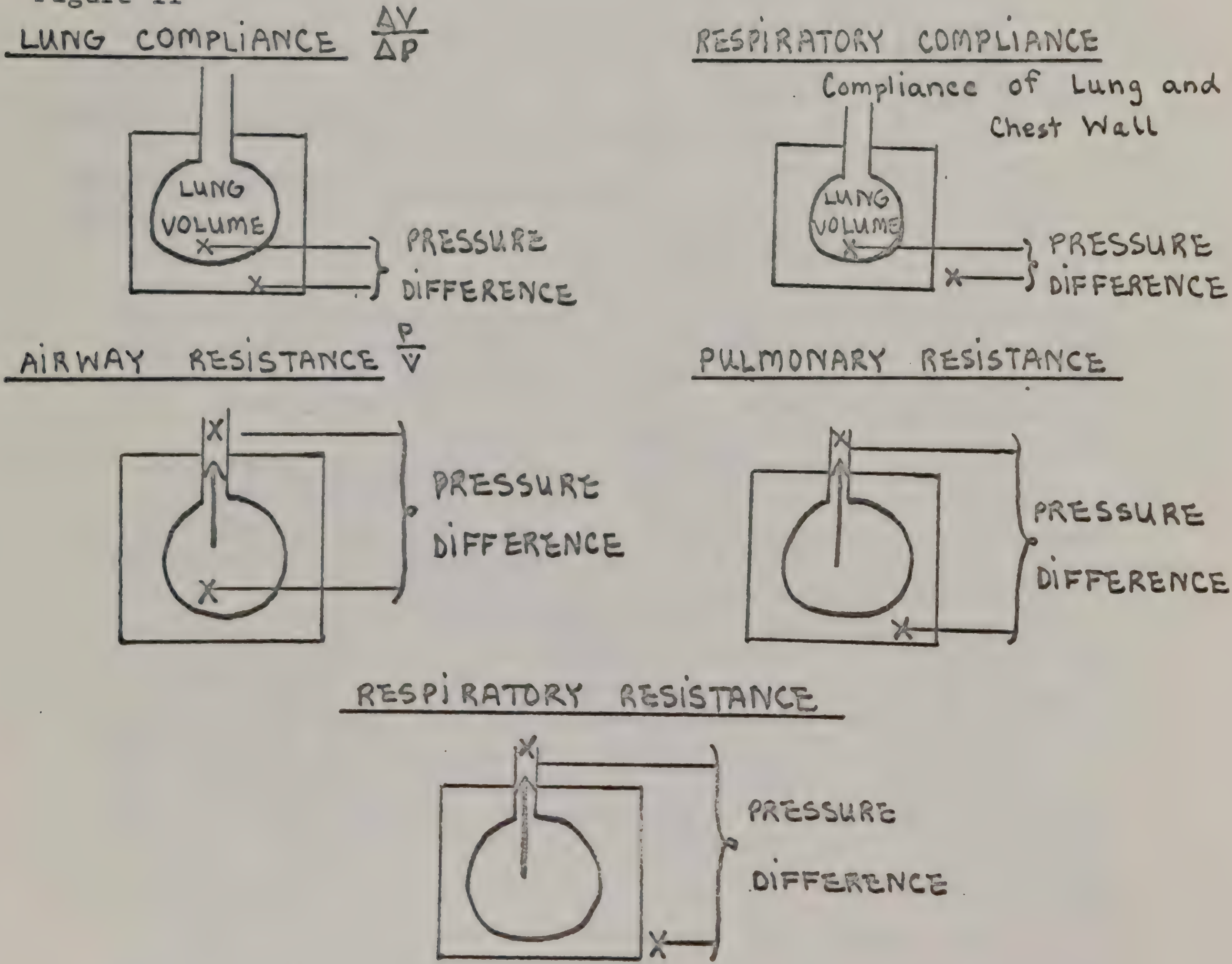


Depending on the site chosen for pressure measurements, one can get figures relating to the airways only, or to the lung, or to the whole respiratory system. Pressure can be measured or estimated in the alveoli, in the pleural cavity, at the mouth or outside the chest.

To measure lung compliance, it is necessary to see how the lung volume depends on the pressure difference between the inside and the outside of the lung. This can be measured in the isolated lung, but in the human subject it is necessary to measure the intrapleural pressure. This can be done by measuring the pressure of the esophageus or by introducing some air into the intrapleural space and measuring the pressure of the air. The compliance of the whole respiratory system is measured much more easily for the pressure difference between the inside of the lung and the outside air only is required. Resistance is measured as the pressure needed to produce a given rate of flow the greater the resistance to flow, the greater the pressure required. The <u>airways resistance</u> gives the relationship between the rate of flow of air from the lungs and the pressure difference between the alveoli and the mouth. One cannot measure the pressure in the alveoli directly, and the <u>airway resistance</u>

is usally determined using whole body plethysmography. The change in chest volume recorded by the plethysmograph indicates how much the air in the alveoli is compressed during expiration, and so its pressure can be calculated. The pulmonary resistance can be measured by recording the relationship between the rate of air flow from the lungs and the intrapleural pressure. It includes the resistance of the airways to air flow and the resistance of the lung tissue to change the shape. The respiratory resistance is the resistance of the whole respiratory system, and can be measured during passive inflation of the thorax. Figure 11 illustrates the principles of compliance and resistance.

Figure 11



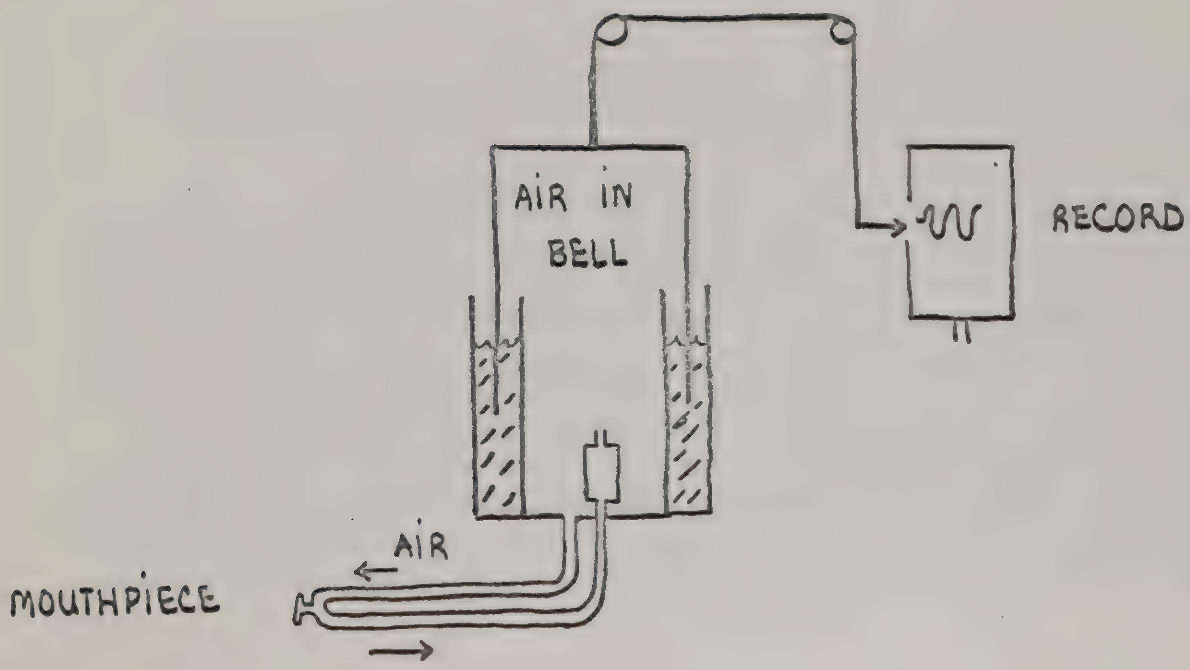
The elasticity of the lung is due in large measure to the surface tension of the fluid lining the alveoli. The alveoli behave like small bubbles, and the surface-tension effect tends to cause them to collapse. In fact, if it were not for the presence of a lipoprotein, the pulmonary surfactant, which reduces the surface tension of the alveolar fluids, the lungs would collapse under normal conditions.

Spirometry

Many studies of lung function, especially studies in disease states, fall under the heading spirometry. The spirometer is simply a device for measuring the volume of air inhaled or exhaled (Figure 12). It consists of an inverted bell floating on water and containing air breathed by the subject through a mouthpiece. Vertical movements of the bell are recorded on a rotating drum and can be read off as volumes of air inhaled or exhaled.

Figure 12

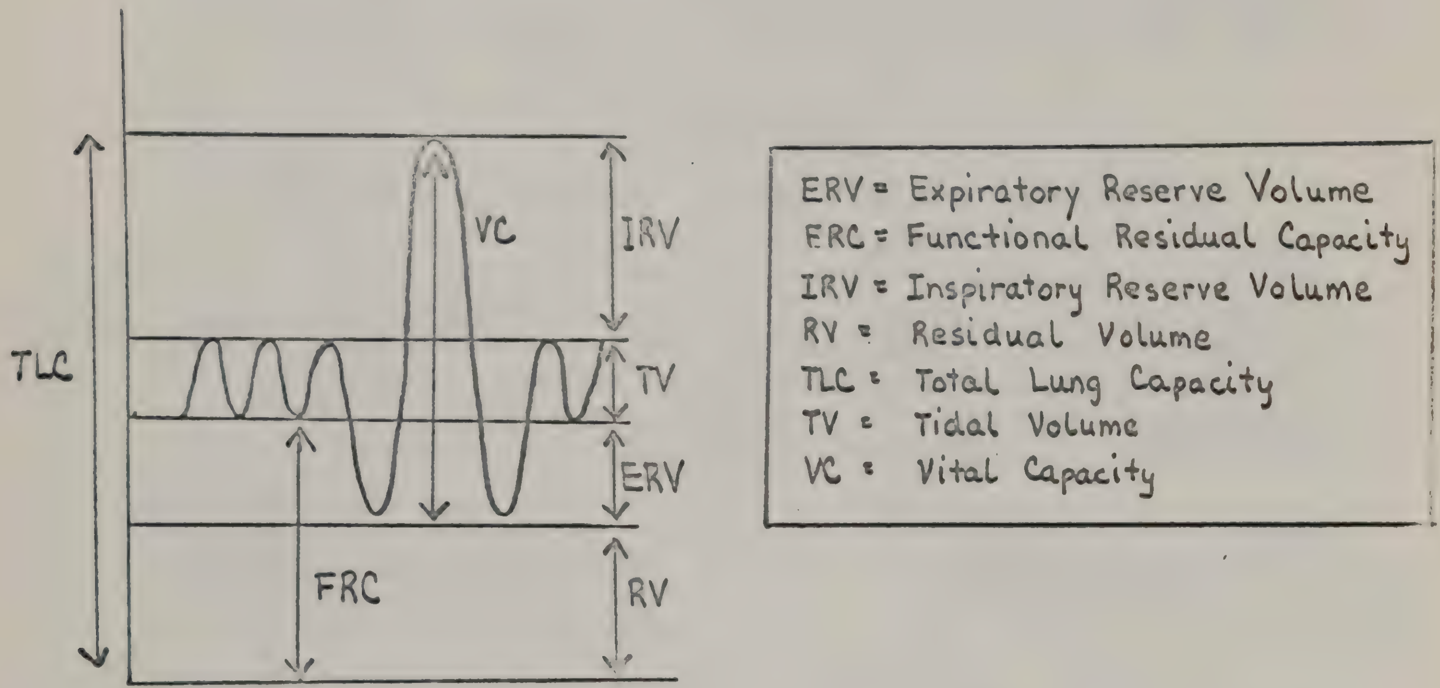
SPIROMETER



By means of spirometry the total lung volume can be divided into a number of components (Figure 13).

Figure 13 . . .

SUBDIVISIONS of LUNG VOLUME

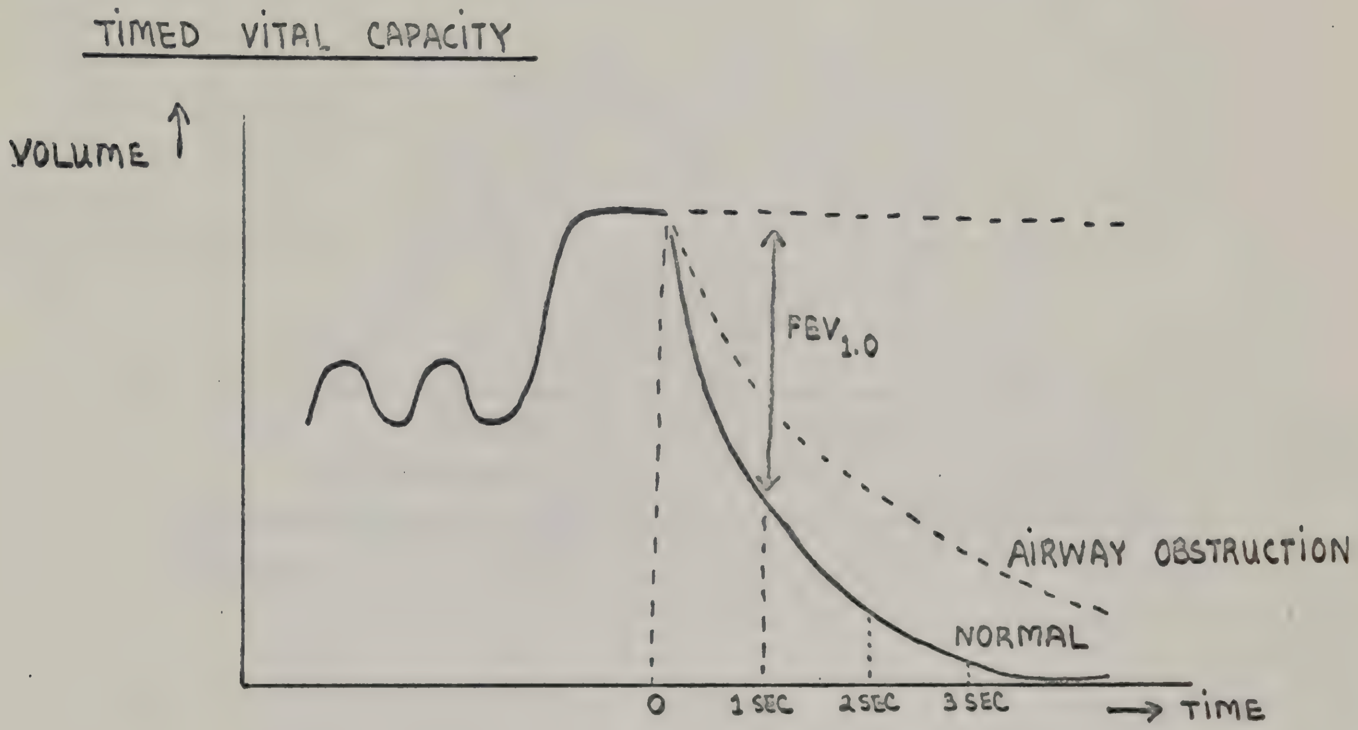


The tidal volume is the amount of air which moves in and out of the lungs during respiration under given conditions. The inspiratory reserve volume is the maximum amount which can be breathed in by making an effort, at the end of a normal inspiration. The expiratory reserve volume is the maximum amount of air that can be breathed out after making a normal expiration. The vital capacity is perhaps the most widely used of these measures of lung volume; it is the maximum amount of air which can be breathed in after forcibly emptying the lungs. The residual volume is the amount of air that is left in the lungs after a maximal expiration. A list of these subdivisions of lung volume and the abbreviations frequently used for them are given in the diagram. Alterations of these volumes are frequently used to diagnose respiratory diseases for in restrictive impairment of lung function the capacity of the lungs is decreased.

Besides these static volume measurements, dynamic studies can be made using spirometry, because the fastest rate at which a subject can breathe in or out depends on the resistance of the airways to the flow of air, and in disease where airway obstruction is present, the resistance is increased.

A commonly used test is the timed vital capacity. (Figure 14)

Figure 14

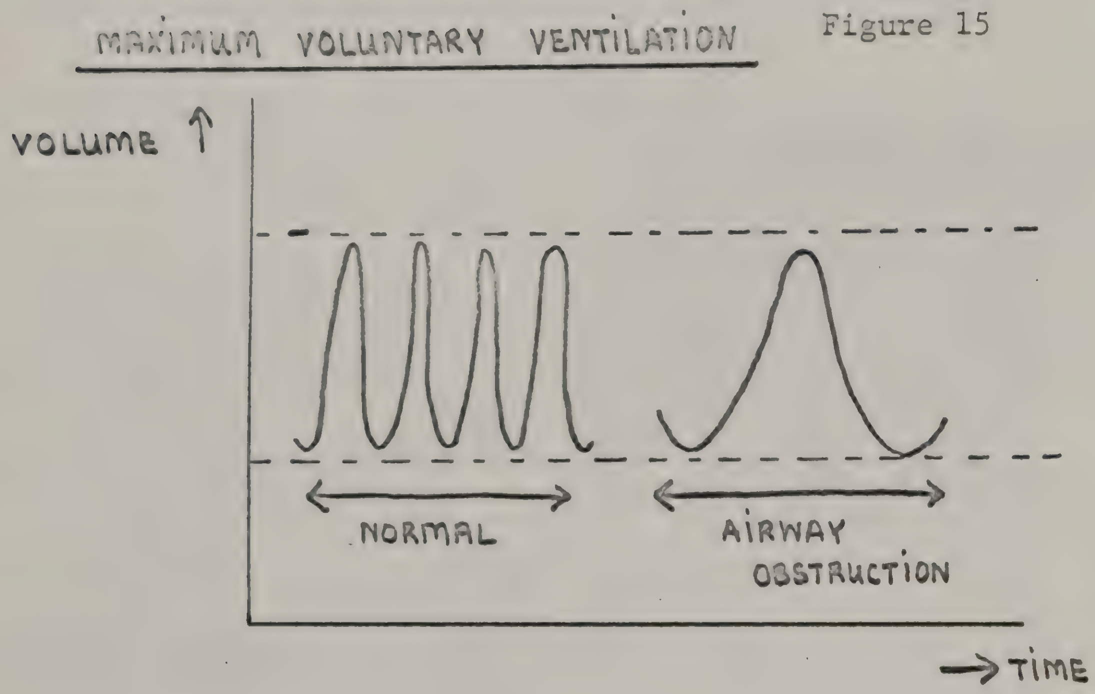


The subject takes a maximal inspiration and then breathes out as rapidly as possible into a spirometer. The most commonly used measure is the $FEV_{1.0}$ (one-second forced expiratory volume). The dotted line on the diagram represents the curve for a patient with airway obstruction and it can be seen that the $FEV_{1.0}$ is much reduced.

Other parameters of this same curve can also be used as a measure of respiratory resistance, for example, the midexpiratory time (MET) and the maximal midexpiratory flow (MMEF).

A spirometer can also be used to record the <u>maximum voluntary ventilation</u> (MVV) (Figure 15), also called the <u>maximal breathing capacity</u> (MBC).

Figure 15



This is the largest volume of air which can be breathed in and out in one minute. This quantity is reduced in obstructive lung diseases.

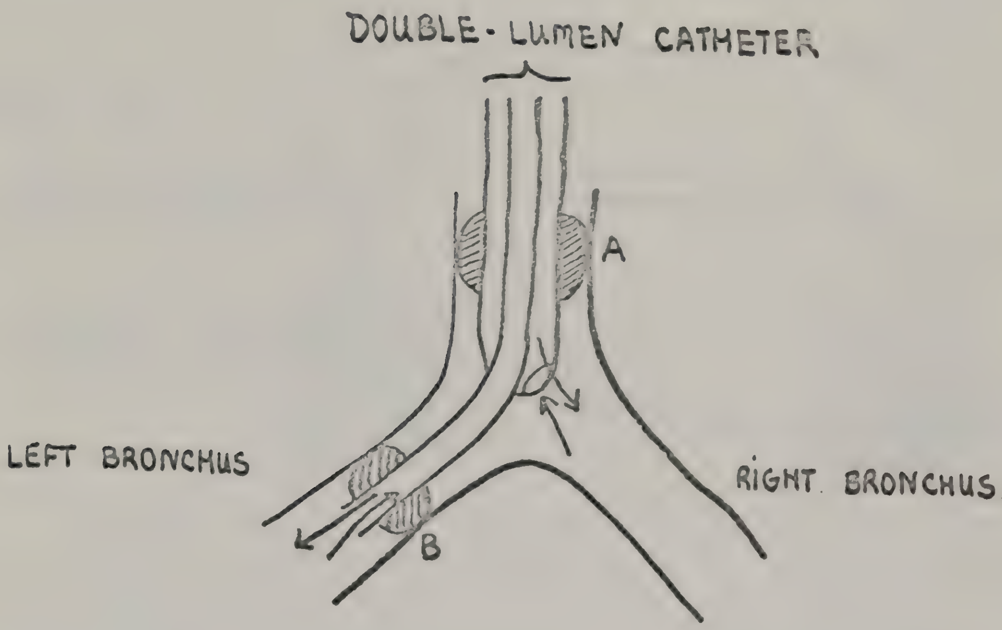
Bronchospirometry

Brochospirometry is a special technic in which the volume of air breathed by the right and left lung is recorded separately. A special double-lumen catheter is

passed down the trachea and inflatable cuffs are used to separate the air flow from the right and left lungs (Figure 16).

Figure 16

BRONCHOSPIROMETRY

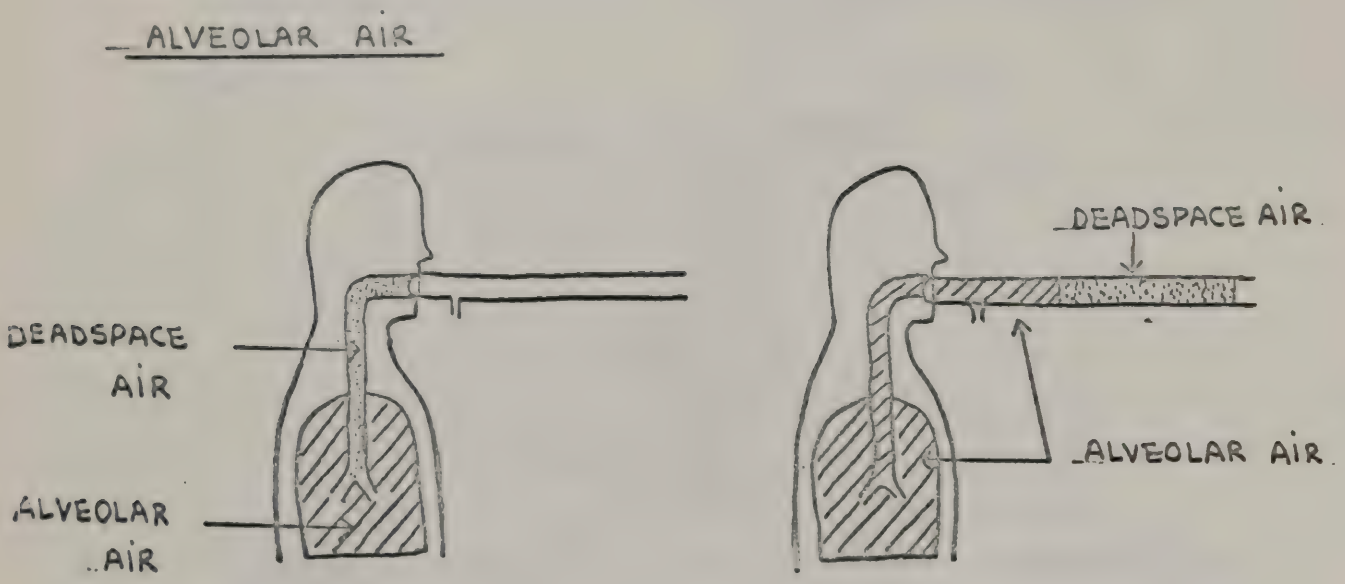


Gas Exchange in the Lungs

As we have seen, gas exchange in the lungs takes place between the air in the alveoli (the alveolar air) and the blood in the alveolar capillaries. The air filling the alveoli forms quite a large reservoir because the the alveoli still contain a considerable volume of air at the end of expiration, and only about 1/5 of the alveolar air is changed at each breath. The composition

of the alveolar air, therefore, remains fairly constant; the partial pressure of oxygen in the alveolar air is about 100mm Hg and the partial pressure of carbon dioxide about 40mm Hg. To get a sample of alveoli air, one has only to breathe out into a long tube. (Figure 17)

Figure 17

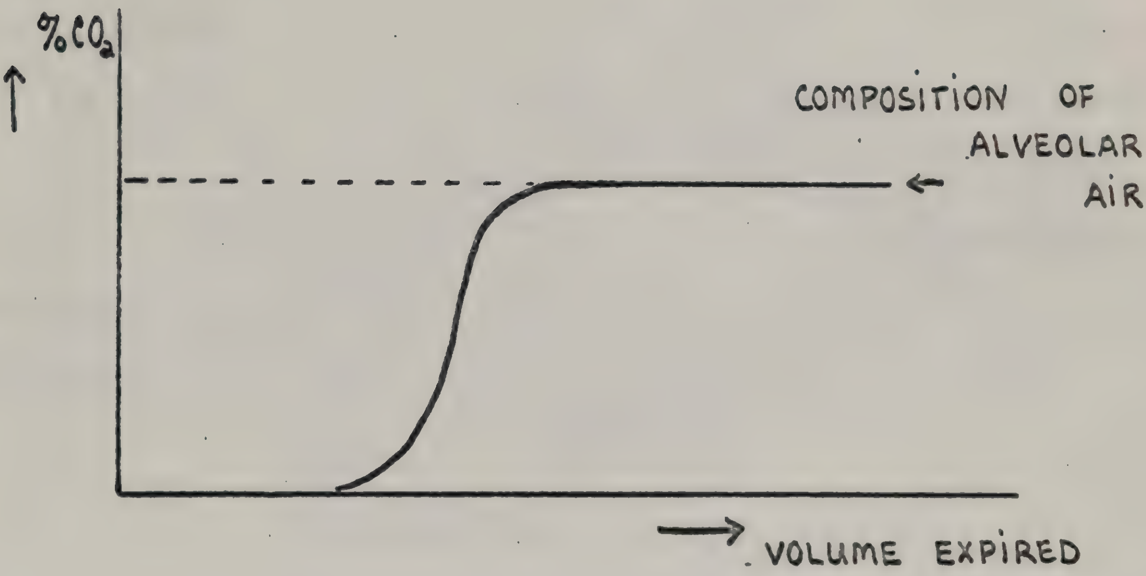


The first air to emerge comes from the trachea and the bronchi--the so-called deadspace air. Deadspace air is similar to room air in composition, but the later fractions of the air breathed out come from the alveoli and reach a fairly uniform composition, that of alveolar air.

In Figure 18, the curve shows the percentage of carbon dioxide in the expired air during the course of

a single expiration. It can be seen that during the later part of the expiration the carbon dioxide content reaches a steady level equal to that in alveolar air.

Figure 18

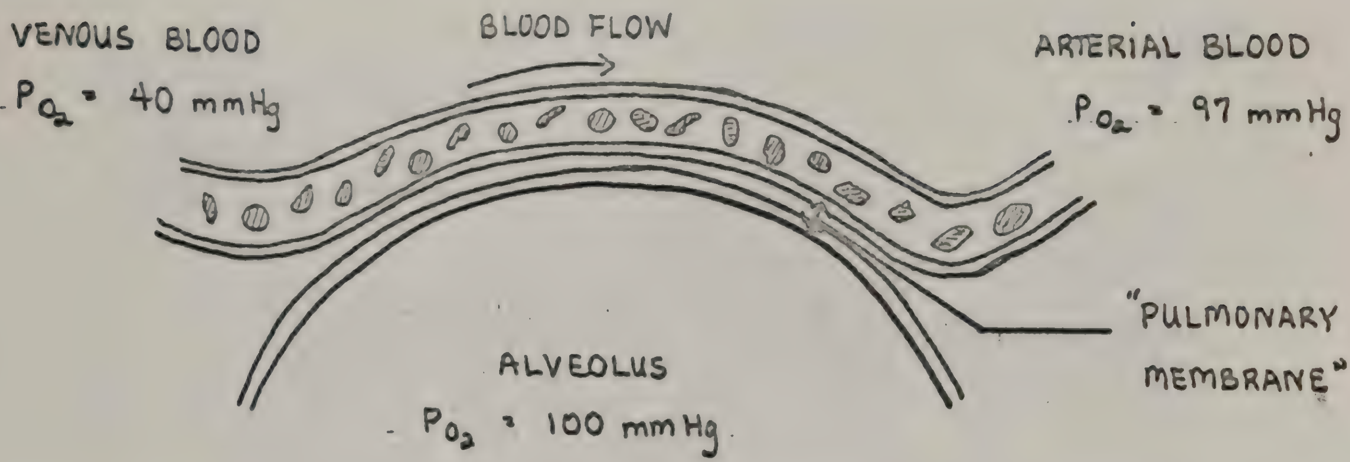


Devices which automatically sample the last few milliliters of each breath--the end tidal air sample--can be used to follow changes in the composition of alveolar air.

Gas exchange takes place between the alveolar air and the capillaries by diffusion. The venous blood which arrives at the lung contains much carbon dioxide and little oxygen. The alveolar air contains much oxygen and little carbon dioxide. The gases diffuse across the

Figure 19

GAS EXCHANGE in ALVEOLI



pulmonary membrane from regions of high concentration to regions of low concentrations (Figure 19). Venous blood arriving in the alveolar capillaries has a P_{O2} (partial pressure of oxygen) of 40mm Hg. The P_{O2} of alveolar air is 100mm Hg. Oxygen diffuses across the pulmonary membrane from the alveolus to the capillary until the blood leaving the alveolus is nearly equilibrated with alveolar air (the partial pressure of oxygen in this "arterial blood" is about 97mm Hg, in comparison with 100mm Hg in the alveolus).

Quantitative measures of this diffusion process are frequently used. The pulmonary diffusing capacity (D_L) is the quantity of gas diffusing across the pulmonary membrane per minute per millimeter of partial pressure difference between the alveolar air and the inside of the erythrocytes in pulmonary capillary blood.

The membrane diffusing capacity (D_M) is the quantity of gas diffusing across the pulmonary membrane per minute

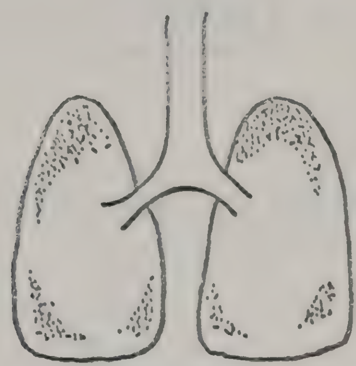
per milliliter of partial pressure difference between the alveolar air and the plasma in the pulmonary capillaries.

The D_L is a measure of diffusion across both the pulmonary membrane and the red cell membrane; the D_M, across the pulmonary membrane alone. The "pulmonary membrane" is composed of the wall of the alveolus and the wall of the capillary, plus any interstitial tissue between. The pulmonary diffusing capacity is most easily measured for carbon monoxide. If a small amount of carbon monoxide is breathed, the hemoglobin in the pulmonary capillaries combines with it all, so that the partial pressure difference between the alveoli and the capillaries is thus very easily measured. The pulmonary diffusing capacity for carbon monoxide (D_{LCO}) is often used as a diagnostic test. In disease, pulmonary diffusion is often impaired due to fibrosis of the alveolar wall or destruction of the alveoli, and the D_{LCO} gives a measure of this.

The lung diffusing capacity of other gases (for example, oxygen) can also be measured, but with less certainty owing to difficulties in calculating the partial pressure difference across the pulmonary membrane.

Figure 20

DISTRIBUTION of VENTILATION

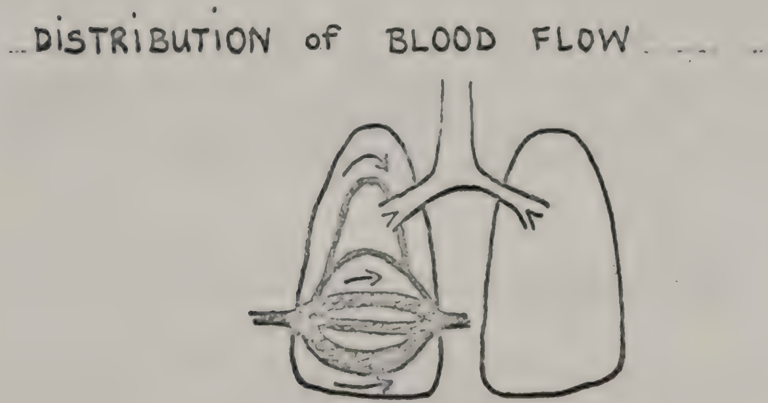


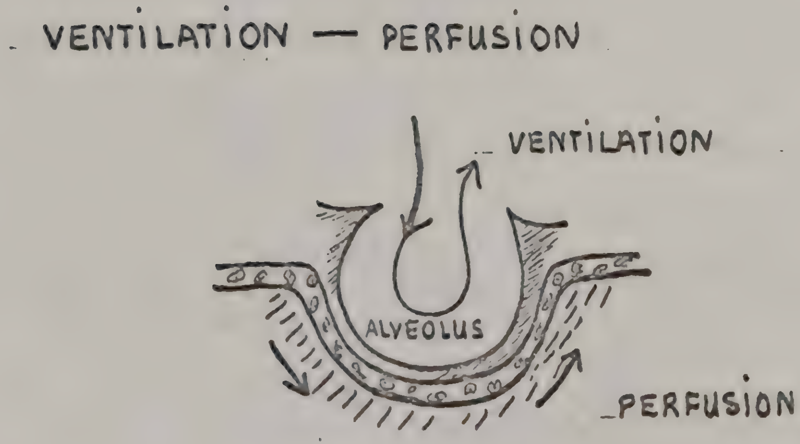
The term ventilation is used for the process of the removal of air in the lungs during breathing. Pulmonary ventilation is simply the amount of air breathed per minute (Figure 20). Alveolar ventilation is simply the amount reaching the alveoli per minute. Not all the air breathed reaches the alveoli: some remains in the airways (this is called deadspace air). Many recent papers deal with

the concept of uneven distribution of ventilation in the lungs. That is, some alveoli are well-ventilated, while the air in others is not renewed very efficiently. Other studies deal with the uneven distribution of blood flow in the lungs.

Note that in Figure 21 the lower part of the lung receives more blood than the upper part. The term ventilation-perfusion ratio is much used for the study of the ratio of ventilation of the alveolus to the blood flow through its capillaries. This subject area can be studied with the aid of radioactive gases, with radioactive carbon dioxide, oxygen and xenon being frequently used.

Figure 21





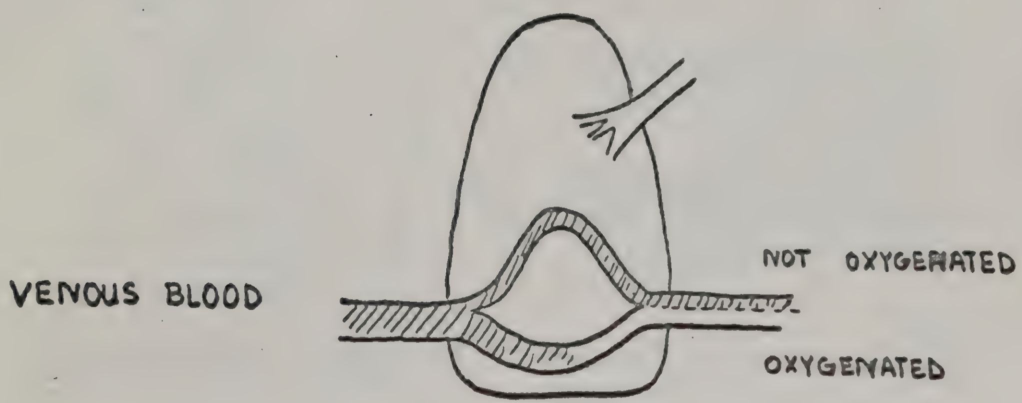
If a subject takes a breath of radioactive carbon dioxide, scanning of the lungs shows most radioactivity in the well-ventilated parts of the lung. The rate of disappearance of the carbon dioxide from different parts of the lung while the subject holds his breath reflects the distribution of blood flow in the lung. It will be carried away more rapidly in regions with a large blood supply.

A simple method of study is to switch a subject from breathing air to breathing oxygen, and to follow the rate of washout of nitrogen from the lung. The nitrogen is cleared rapidly from well-ventilated areas, but not from the poorly ventilated parts of the lung.

If some of the blood flowing through the lung passes through alveoli which are not ventilated at all, it is as though venous blood had been mixed with arterial blood. This is referred to as venous admixture or pulmonary arteriovenous shunt (Figure 22).

Figure 22

PULMONARY ARTERIOVENOUS SHUNT



The difference between the P_{O_2} in arterial blood and that in the alveoli gives a measure of the amount of blood passing through the lung without being oxygenated. This is called the alveolar-arterial oxygen gradient.

Symbols in Respiration Physiology

In much of the work on gas exchange, authors use an internationally accepted set of symbols. Thus, "V" stands for gas volume, "p" for gas pressure, "Q" for volume flow of blood, and so on. The subscript "I" means inspired gas and "A," alveolar gas, while the subscript "a" means arterial blood and "b," venous blood. These symbols can be combined to express many different concepts. Thus $P_{A_{O_2}}$ is alveolar partial pressure of oxygen, while Pa_{O_2} is the partial pressure of oxygen in arterial blood. $\dot{V}_{O_2}$ is volume of oxygen per unit time and can be used to mean the rate of oxygen consumption. $F_{E_{CO}}$ is the fraction of carbon monoxide in the expired air, while $\frac{\dot{V}_A}{\dot{Q}}$ is the ventilation perfusion ratio. Since these symbols are often used by authors without being defined in the text, indexers should be familiar with them (Figure 23).

Figure 23

GENERAL VARIABLES		SUBSCRIPTS	
V	Gas volume	I	Inspired gas
$\dot{V}$	Gas volume per unit time	E	Expired gas
P	Gas pressure	A	Alveolar gas
F	Fractional concentration	T	Tidal gas
Q	Volume flow of blood	D.	Deadspace air
C	Concentration	B	Barometric
f	Respiratory frequency	b	Blood
R	Respiratory exchange ratio	a	Arterial
D	Diffusing capacity	v	Venous
		c	Capillary

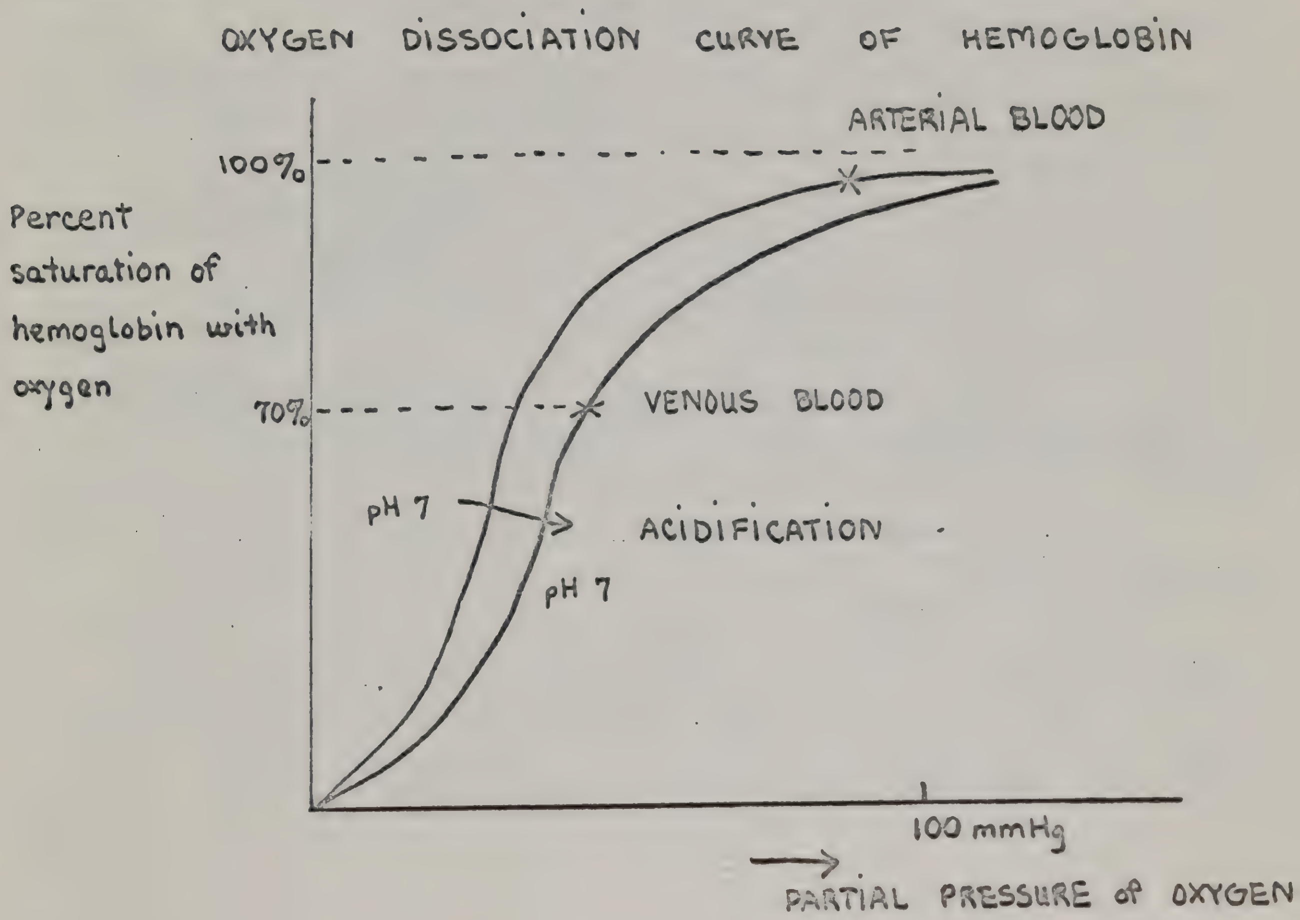
$P_{A_{O_2}}$	partial pressure of oxygen in alveolar air
Pa_{O_2}	partial pressure of oxygen in arterial blood
V_{O_2}	oxygen consumption
$F_{E_{CO}}$	fraction of CO_2 in the expired air
$\frac{\dot{V}_A}{\dot{Q}}$	ventilation-perfusion ratio

Transport of Gases in the Blood

Oxygen and carbon dioxide are transported in the blood from the lungs to the tissues, the oxygen in combination with hemoglobin in the erythrocytes and the carbon dioxide mainly as bicarbonate in the plasma but also partly in combination with blood proteins, including hemoglobin. Hemoglobin, therefore, plays a part in the transport of both oxygen and carbon dioxide.

When the partial pressure of oxygen is high (as it is in the lungs), four molecules of oxygen can combine with one molecule of hemoglobin to form oxyhemoglobin. When the partial pressure of oxygen is low (as it is in the tissues) the oxyhemoglobin gives up its oxygen. The curve relation, the percent oxygen saturation of hemoglobin with the partial pressure of oxygen in the blood, is called the <u>oxygen dissociation curve</u> of hemoglobin (Figure 24).

Figure 24



The diagram shows that the percentage saturation of hemoglobin with oxygen is nearly 100% at the partial pressure of oxygen found in arterial blood, and is about 70% at the partial pressure found in venous blood at rest. Thus in a subject at rest about ¼ of the oxygen carried by hemoglobin in arterial blood is given up to the tissues. This fraction, which is termed the coefficient of oxygen utilization, may be much greater in exercise, when the concentration of oxygen in the tissues is very low. The oxygen dissociation curve shifts to the right when blood is acidified or when CO_2 is added as it is in the tissues. This shift helps the hemoglobin to give up its oxygen, and is called the Bohr effect.

Carbon dioxide transport in the blood is closely linked with the ACID-BASE EQUILIBRIUM of the body. Carbon dioxide reacts with water to produce carbonic acid, and if it was not for the buffering action of the plasma proteins and of bicarbonate present in the blood, the pH of the blood would not remain as stable as it does at pH 7.3-7.6. In respiratory alkalosis, hyperventilation lowers the blood CO_2 below normal.

Blood gas analysis used to be carried out by laborious chemical methods, but it is now usually done polarographically using membrane-covered electrodes such as the Clark oxygen electrode, which can give a continous record of blood gas composition. The degree of oxygen saturation of the blood can be recorded continuously using an oximeter. This is a photoelectric colorimeter which can sense the difference between the colors of oxygenated and deoxygenated hemoglobin.

In indexing this subject area, studies of the oxygen dissociation curve or gas transport by hemoglobin should be indexed with HEMOGLOBIN and OXYGEN *blood, both print.

The term BLOOD GAS ANALYSIS is used only for studies of the technic of blood gas analysis, and not as a synonym for analysis of oxygen.

Studies of blood pH should be indexed with HYDROGEN-ION CONCENTRATION and with the term BLOOD, both print (the subheading *blood cannot be used with HYDROGEN-ION CONCENTRATION which is in Category H of MeSH). Thus an article on the effect of hyperventilation on blood P_{O2} , P_{CO2} , and pH

should be indexed with HYPERVENTILATION, OXYGEN *blood, CARBON DIOXIDE *blood, HYDROGEN-ION CONCENTRATION and BLOOD.

Subheadings with OXYGEN and CARBON DIOXIDE

The use of some subheadings available to Category D (Chemicals and Drugs) with OXYGEN and CARBON DIOXIDE can give misleading results. In the MEDLARS system the subheading *pharmacodynamics used with names of drugs and chemicals is used in the sense of "the effect of an exogenously administered drug or chemical." *pharmacodynamics should not be used with respect to OXYGEN and CARBON DIOXIDE. Thus, a paper on the effect of breathing oxygen in the heart rate should be indexed not with OXYGEN *pharmacodynamics and HEART RATE *drug effects but simply as with OXYGEN and HEART RATE.

The combination OXYGEN *metabolism should not be used; the term OXYGEN CONSUMPTION is preferred. CARBON DIOXIDE *metabolism may be used for the production of carbon dioxide in cellular respiration or for quantitative studies of the amount of carbon dioxide produced by the entire organism, but not for gas exchange in the lung or for blood transport of carbon dioxide.

The subheading *physiology should not be used with either OXYGEN or CARBON DIOXIDE. Articles on the physiological role or OXYGEN in breathing should be indexed with the term OXYGEN without any subheadings. It would be logical to use OXYGEN *physiology for studies of oxygen exchange in the lungs or the effects of breathing oxygen, but the subheading *physiology cannot be used in the system for an exogenous chemical. Carbon dioxide may be endogenous, but to avoid treating the two gases in different ways, the same rule will apply here: omit the subheading *physiology.

GLOSSARY AND INDEXING INSTRUCTIONS

This glossary lists terms commonly seen in articles on respiratory physiology. Official definitions supplied by Medical Subject Headings (MeSH) are printed here as given. It was not felt necessary to define such terms as THORAX, LUNG, etc.

ACIDOSIS, RESPIRATORY (C5) 1968
an abnormal condition due to excess retention of carbon dioxide in the body and resulting in an increase in hydrogen ion concentration in the body fluids; the retention in this case is the result of the failure to adequately clear the blood of carbon dioxide by reason of pulmonary disease. (MeSH definition)

airways obstruction
mechanical blockage of airways
Index RESPIRATORY TRACT DISEASES (68)

airways resistance
relationship between the rate of flow of air from the lungs and the pressure difference between the pulumonary alveoli and the mouth
Index RESPIRATORY SYSTEM *physiology(68)

alkalosis, respiratory
blood carbon dioxide below normal because of hyperventilation
Index ALKALOSIS (IM) (68)
HYPERVENTILATION (IM) (68)

alveolar air
air in the pulmonary alveoli
Index RESPIRATION (IM) (68)
PULMONARY ALVEOLI (IM) (68)

alveolar-arterial oxygen gradient
amount of blood passing through the lung without being oxygenated

alveolar capillaries
the capillaries of the pulmonary alveoli
Index PULMONARY ALVEOLI (IM) (68)
CAPILLARIES (IM) (68)

alveolar duct
passageway in air cells
Index PULMONARY ALVEOLI (68)

alveolar sac
the covering around the air cells
Index PULMONARY ALVEOLI (68)

alveolar ventilation
amount of air reaching alveoli per minute
Index PULMONARY ALVEOLI (IM) (68)
RESPIRATION (IM) (68)

alveoli, pulmonary
the air cells in the lung
Index PULMONARY ALVEOLI (68)

BASAL METABOLISM (G1)
turnover of energy in a fasting and resting organism to maintain cellular activity; determined with subjects in a basal state (awake, after eating, and at rest at a comfortable environmental temperature)

basal oxygen consumption
respiration in a resting organism
Index BASAL METABOLISM (68)

basal state
awake but at rest; in reference to conditions under which basal metabolism is measured; see BASAL METABOLISM
Index BASAL METABOLISM (68)

BLOOD GAS ANALYSIS (E1)

blood pH
measure of acidity or basicity of the blood
Index HYDROGEN-ION CONCENTRATION (IM)(68)
BLOOD (IM) (68)

Bohr effect
shift of the oxygen dissociation curve to the right when the blood is acidified, thus helping hemoglobin to give up oxygen
Index HEMOGLOBIN (IM) (68)
OXYGEN *blood (IM) (68)
HYDROGEN-ION CONCENTRATION (NIM) (68)

BRONCHI (A4) 1963

bronchiole
a branch of the bronchus
Index BRONCHI (68)

bronchoconstriction
Index BRONCHI *physiology (IM) (68)
CONSTRICTION (Prov) (NIM) (68)

bronchodilatation
Index BRONCHI *physiology (IM) (68)
DILATATION (Prov) (NIM) (68)

BRONCHOSPIROMETRY (E1)
spirometric technic in which the volume of air breathed in the right and left lung is recorded separately

buffering action
action that keeps the pH stable
Index BUFFERS (68)

CALORIMETRY (H) 1968
measurement of the amounts of heat absorbed ot given out, also the technic for determining specific heats (MeSH definition)

calorimetry, direct
direct measure of heat production of a subject with the subject in a calorimeter; does not refer to theoretical aspects of energy metabolism
Index CALORIMETRY (68)

calorimetry, indirect
measure of oxygen consumption; does not measure actual heat production
Index OXYGEN CONSUMPTION (68)

cell respiration
Index OXYGEN CONSUMPTION (68)

chest wall
the limiting structure of the chest
Index THORAX (68)

coefficient of oxygen utilization
the fraction of oxygen carried by hemoglobin in arterial blood that is given up to the tissues
Index OXYGEN CONSUMPTION (68)

compliance (G1) (Prov) (68)
the capacity of an organ or tissue to resist change in size or shape and to return to its orginal state following removal of the stress
See also LUNG COMPLIANCE (Prov)
Index appropriate main heading
*physiology or *physiopathology
ELASTICITY (68)

constriction (C17,E4,G1)(Prov) (68)
narrowing or reducing in size; in medicine it usually refers to the narrowing of the lumen of an organ producing increased resistance to flow
Index appropriate main heading (IM)(68)
CONSTRICTION (Prov) (NIM) (68)

deadspace air
first air to emerge from the trachea and bronchi during respiration
Index RESPIRATION (68)

deoxygenated hemoglobin
hemoglobin with oxygen removed
Index HEMOGLOBIN (68)

DIAPHRAGM (A2)

diffusion (G1,H) (Prov) (68)
the spontaneous mixing of one substance with another; usually refers to the passage of substances from regions of high concentration to low without significant energy requirement
Index BIOPHYSICS (IM) (68)
CHEMISTRY, PHYSICAL (IM) (68)

dilatation (C17,E4,G1) (Prov) (68)
increase in size by stretching or expansion; usually refers to increase in diameter of the lumen of an organ
Index appropriate main heading and subheading

D_L
see pulmonary diffusing capacity

D_M
see membrane diffusing capacity

end tidal air sample
sample of the last few milliliters of each breath
Index SPIROMETRY (68)

energy cost
Index METABOLISM (68)
or
BASAL METABOLISM (68)

energy expenditure
Index METABOLISM (68)
or
BASAL METABOLISM (68)
or
OXYGEN CONSUMPTION (68)

energy metabolism
Index METABOLISM (68)
or
BASAL METABOLISM (68)
or
OXYGEN CONSUMPTION (68)

membrane diffusing capacity
quantity of gas diffusing across the pulmonary membrane per minute per milliliter of partial pressure difference between the alveolar air and the plasma in the pulmonary capillaries; D_M
Index RESPIRATION (IM) (68)
PULMONARY ALVEOLI *physiology (IM) (68)
DIFFUSION (Prov) (NIM) (68)

MET
see midexpiratory time

metabolic rate
rate of energy production of the whole body; usually expressed in kilocalories per day
Index METABOLISM (68)

METABOLISM (G1)
chemical and energy changes in the organism or specified parts

midexpiratory time
spirometric technic for measurement of respiratory resistance
Index SPIROMETRY (IM) (68)
RESPIRATORY SYSTEM *physiology (IM) (68)

MMEF
see maximal midexpiratory flow

MVV
see maximum voluntary ventilation

OXIMETRY (E1)
measurement of oxygen saturation of blood; a specific technic, not a synonym for the determination of blood oxygen

OXYGEN CONSUMPTION (G1)
syn. Qo2, rate of respiration
the volume of oxygen consumed by a cell (at STP) per unit weight of organism, per unit time
(MeSH definition: Geise Cell Physiology, 1962, p. 370; Davson: Textbook of Physiology, 1964, p. 186)

oxygen dissociation curve
percent of oxygen saturation of hemoglobin with partial pressure of oxygen in the blood
Index HEMOGLOBIN (IM) (68)
OXYGEN *blood (IM) (68)

oxygen saturation of blood
amount of oxygen contained in the blood
Index OXYGEN *blood (68)

oxygenated hemoglobin
hemoglobin of arterial blood, combined with oxygen
Index HEMOGLOBIN (68)

oxyhemoglobin
a compound formed from hemoglobin on exposure to air, with formation of a covalent bond with oxygen and without change of the charge of the ferrous state
Index HEMOGLOBIN (68)

PARTIAL PRESSURE (H)
the pressure exerted by an individual gas in a mixture of gases; the sum of the partial pressures of individual gases is equal to the total pressure (MeSH definition; Fulton: Textbook of Physiology)

pH of the blood
measure of acidity of basicity of the blood
Index HYDROGEN-ION CONCENTRATION (IM)(68
BLOOD (IM) (68)

PHARYNX (A3) 1964

plethysmography, whole body
a method for measuring alveolar pressure indirectly; based on changes in chest volume to show how much air in alveoli is compressed during expiration
Index PLETHYSMOGRAPHY (68)

PLEURA (A4)

pleural cavity
Index PLEURA (68)

PNEUMOTHORAX (C5)
condition occurring if chest wall is perforated, causing the lung to collapse and the pleural cavity to fill with air

pulmonary arteriovenous shunt
see venous admixture

pulmonary diffusing capacity
quantity of gas diffusing across the pulmonary membrane per minute per milliliter of partial pressure difference between the alveolar air and the inside of the erythrocytes in pulmonary capillary blood; D_L.
Index RESPIRATION (IM) (68)
PULMONARY ALVEOLI *physiology (IM) (68)
DIFFUSION (NIM) (68)

pulmonary membrane
includes the wall of the alveolus, the wall of the capillary and any interstitial tissue between
Index PULMONARY ALVEOLI (IM) (68)
CAPILLARIES (NIM) (68)

pulmonary resistance
includes the resistance of airways to air flow and the resistance of lung tissue to change shape
Index LUNG *physiology (68)

pulmonary surfactant
lipoprotein that reduces tension of the pulmonary alveolar fluids
Index LUNG *physiology (IM) (68)
SURFACE-ACTIVE AGENTS (IM) (68)
SURFACE PROPERTIES (Prov)(NIM)(68)
LIPOPROTEINS (IM) (68)

pulmonary ventilation
Index RESPIRATION (68)

residual volume
amount of air left in the lungs after forced expiration
Index SPIROMETRY (68)

RESPIRATION (G1)
gas exchange between an organism and the environment, an essential feature of most living systems; intake of air through the lungs, gills, air tubes, etc.

respiratory acidosis
see ACIDOSIS, RESPIRATORY

respiratory airways
Index RESPIRATORY SYSTEM (68)

respiratory alkalosis
see alkalosis, respiratory

respiratory compliance
compliance of lung and chest wall
Index RESPIRATORY SYSTEM *physiology (IM) (68)
COMPLIANCE (Prov) (NIM) (68)

respiratory physiology
includes the mechanics of respiration and activities involved in gas exchange and oxygen consumption
Index RESPIRATION without the subheading *physiology (68)

respiratory resistance
resistance of the whole respiratory system
Index RESPIRATORY SYSTEM *physiology (IM) (68)
RESISTANCE (Prov) (NIM) (68)

resting metabolism
chemical changes in a quiet or resting organism or organ
Index BASAL METABOLISM (68)

RV
see residual volume

SPIROMETRY (E1)
measurement of volume of air inhaled or exhaled by the lung; applicable to various degrees of the respiratory process

SURFACE TENSION (H)
a resistance that acts to preserve the integrity of a surface

thoracic cavity
space in which heart and lungs lie
Index THORAX (68)

THORAX (A, A2, A4)

tidal volume
amount of air which moves in and out of the lungs during respiration under given conditions
Index SPIROMETRY (68)

timed vital capacity
spirometric technic in which the subject takes a maximal inspiration, then breathes out as rapidly as possible into a spirometer. The measure is the $FEV_{1.0}$ (one-second forced expiratory volume)
Index SPIROMETRY (IM) (68)
TIME FACTORS (NIM) (68)

tissue metabolism
see tissue respiration

tissue respiration
use of oxygen by tissue cells for their metabolic processess
Index OXYGEN CONSUMPTION (68)

TLC
see total lung capacity

total lung capacity
syn. TLC
Index SPIROMETRY (68)

TRACHEA (A4)

TV
see tidal volume

uneven distribution of blood flow
some parts of the lungs receive more blood than the other parts
Index PULMONARY CIRCULATION (68)

VC
see vital capacity

venous admixture
the flowing of blood through the lung, passing through alveoli which have not been ventilated; comparable to the mixing of venous blood with arterial blood
Index PULMONARY CIRCULATION (IM) (68)
RESPIRATION (IM) (68)
PULMONARY ALVEOLI (NIM) (68)

venous blood
blood arriving at the lung; contains much CO_2 and little O_2
Index BLOOD (IM) (68)
VEINS (NIM) (68)

ventilation
flushing of air in lungs during breathing
Index RESPIRATION (68)

VENTILATION-PERFUSION RATIO (E1)(Prov)(68)
the ratio between the total air entering the lung to the blood flow through the lung during a specified time period; usually measured as a function of oxygen exchange
Index RESPIRATORY FUNCTION TESTS (IM)(68)
PULMONARY CIRCULATION (IM) (68)

ventilation, pulmonary
see pulmonary ventilation

vital capacity
syn. VC
maximum amount of air that can be breathed in after forcibly emptying the lungs
Index SPIROMETRY (68)

whole body plethysmography
see plethysmography, whole body